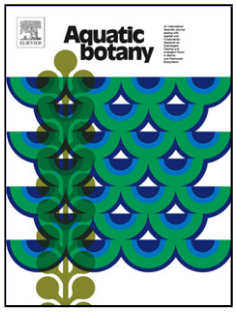

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Five decades of dramatic changes in submerged vegetation in Lake Constance

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Highlights

- Lake Constance has continued to develop a more oligotrophic species composition
- Charophyte species richness and abundance have continued to greatly increase
- Changes appear most strongly related to dramatically reduced total phosphorus levels
- Recovery has occurred in a rapid and extensive fashion

Abstract

Lake Constance is the second largest lake in Europe. While naturally oligotrophic, the lake experienced a period of heavy eutrophication due to the input of domestic and industrial sewage and agricultural runoff in the 1960s and 1970s. This prompted concerted efforts from authorities to purify wastewaters and reduce agricultural nutrient input, initiating a phase of re-oligotrophication since the 1990s. Using environmental and submerged vegetation data from 1967 to 2016, our objective was to analyse the temporal vegetation developments in the lake through the early periods of eutrophication and later periods of re-oligotrophication. Shifts in general vegetation functional groups and nutrient-dependent macrophyte indices were compared with changes in water temperature, Secchi transparency and concentrations of total phosphorus and nitrogen. During the period of eutrophication, the lake was dominated by filamentous algae and tall, thin leaved macrophyte species. Upon reduction of lake phosphorus concentrations, from the 1990s onwards there was a rapid and marked increase in species richness, and charophytes emerged as the dominant species group. Charophytes showed a remarkable recovery from just two species in 1978 to ten species by 2016. These changes were primarily dictated by changing phosphorus concentrations that played a crucial role in interspecific competition. The close